

FIG. 1

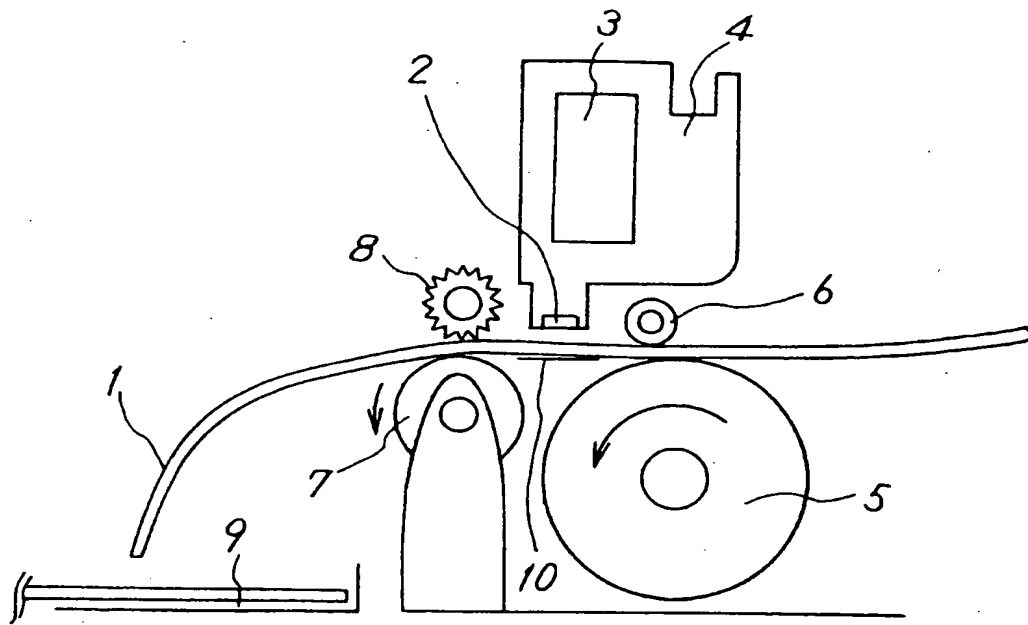


FIG. 2

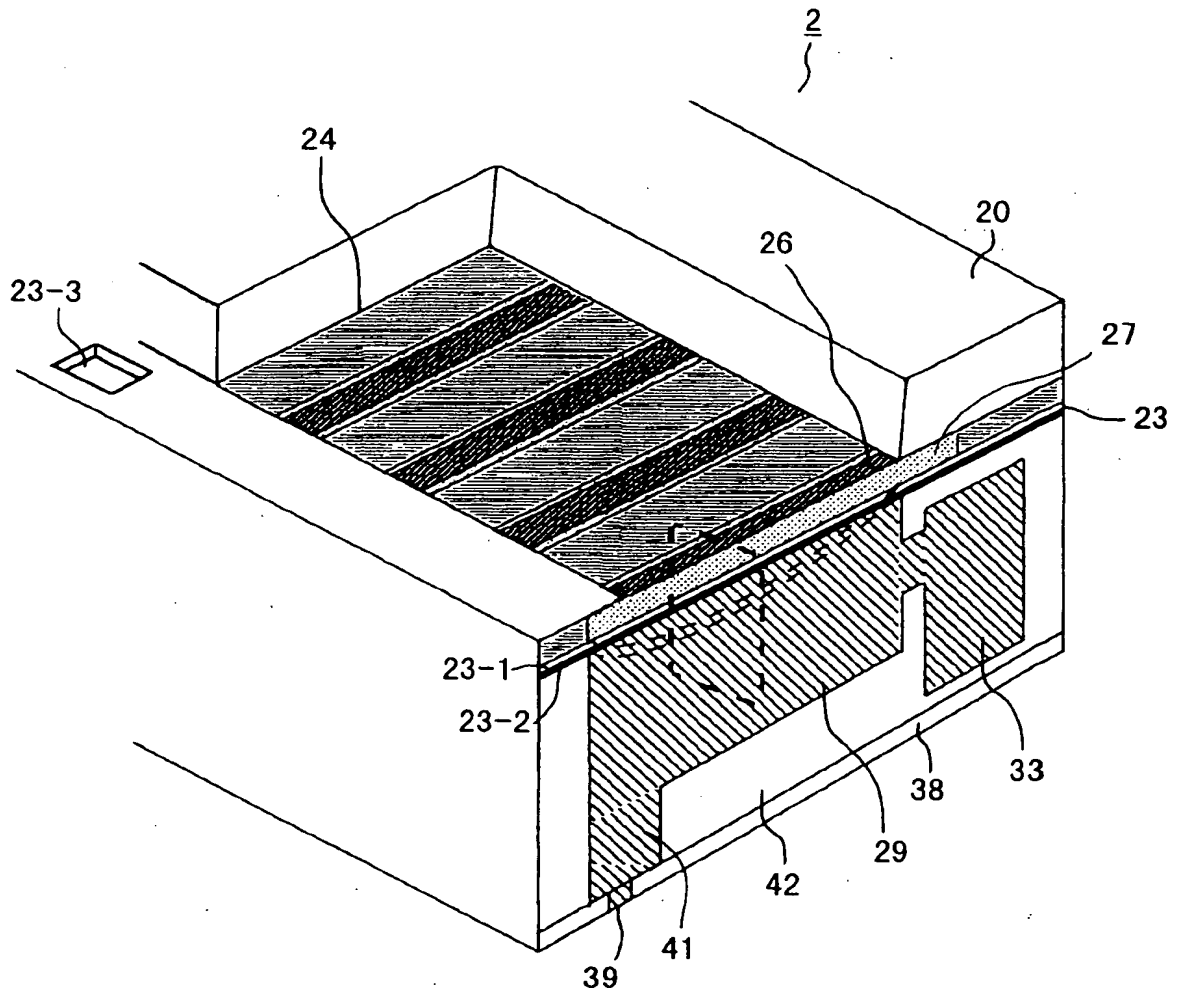


FIG. 3

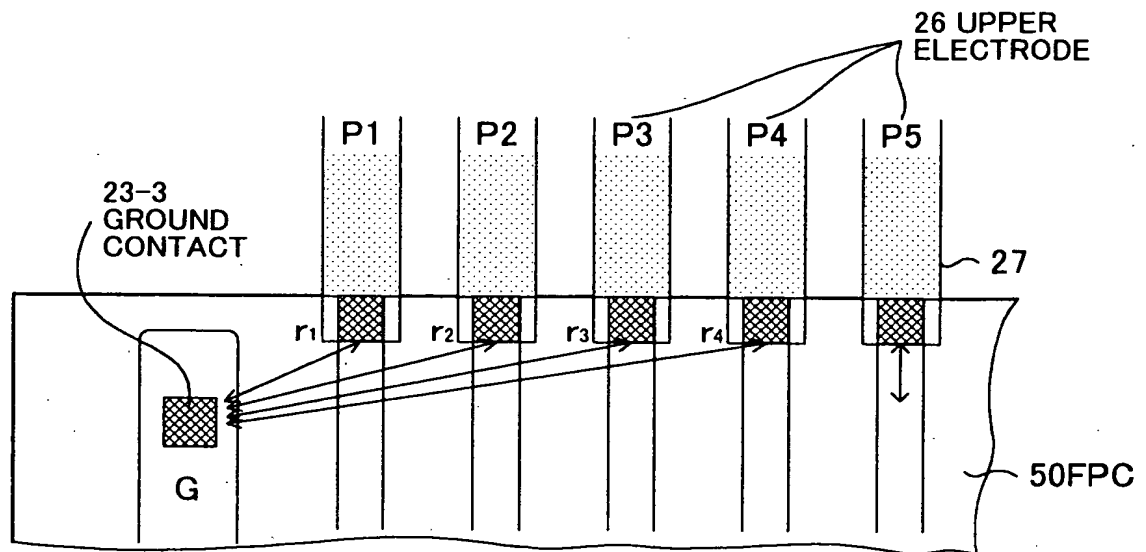
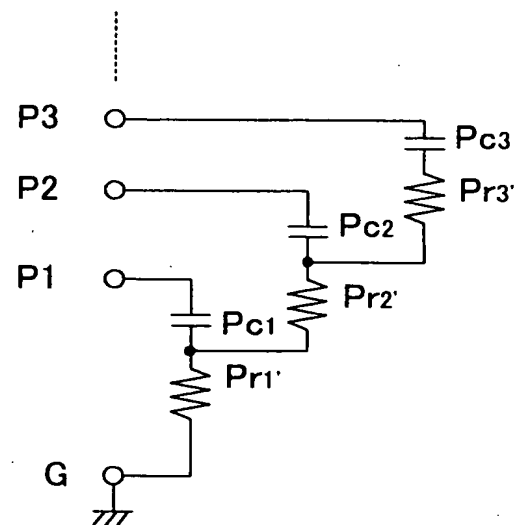
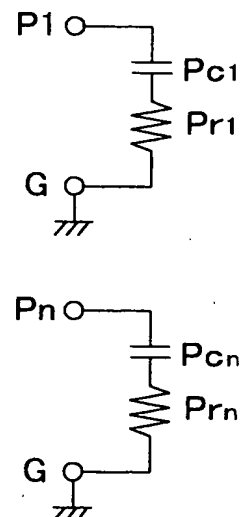


FIG. 4



WHEN A PLURALITY OF PIN DRIVE



$$Pc1 = Pc_n \quad Pr1 \leq Pr_n$$

WHEN A SINGLE-PIN DRIVE

FIG. 5

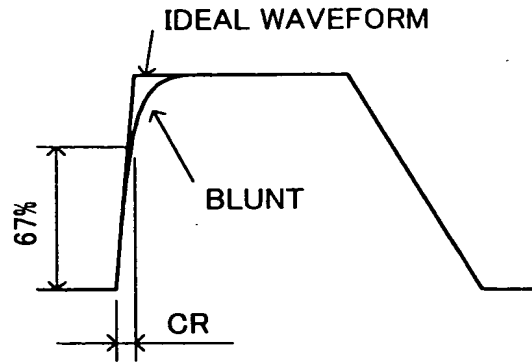


FIG. 6

PRESSURE CHAMBER LENGTH $L_c(m)$	7.00E-04
SIGNAL LINE LENGTH L_{sig}	1.00E-04
PIEZO THICKNESS $t_p(m)$	1.00E-06
PIEZO WIDTH $w_p(m)$	7.00E-05

VACUUM PERMITTIVITY ϵ_0	8.85E-12
PIEZO SPECIFIC PERMITTIVITY ϵ / ϵ_0	420

PIEZO CAPACITANCE $C_p(pF)$	208.152
$C_p = \epsilon * (L_v + L_{sig}) * w_p / t_p$	

RESISTANCE CR : $\rho (\Omega \cdot m)$	1.27E-07
---	----------

NOZZLE PITCH (m)	1.70E-04		
THE NUMBER OF NOZZLES	64		
COMMON ELECTRODE LENGTH (m)	5.44E-03	←DISTANCE FROM BOTH ENDS OF 64 PIN ARRANGEMENT	
APPLIED VOLTAGE (V)	20		
WAVEFORM RISE TIME (ns)	50	SINGLE PIN DRIVE (pF)	208.152
		ALL PIN DRIVE (pF)	13321.7

FIG. 7

CrTHICKNESS	0.1	0.2	0.3	0.4	0.5	0.6
RESISTANCE	11.5147	5.75733	3.83822	2.87867	2.30293	1.91911
1-CR	2.4E-09	1.2E-09	8E-10	6E-10	4.8E-10	4E-10
all-CR	1.5E-07	7.7E-08	5.1E-08	3.8E-08	3.1E-08	2.6E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

FIG. 8

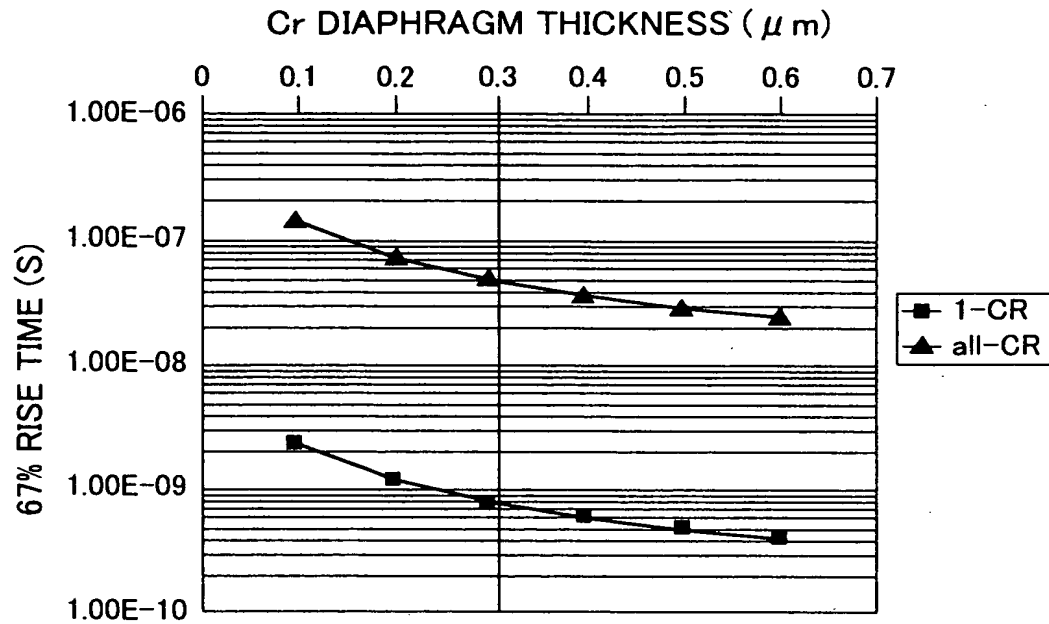


FIG. 9

RESISTANCE Ni : $\rho (\Omega \cdot \text{m})$ 7.24E-08

Ni THICKNESS	0.1	0.15	0.2	0.25	0.3	0.35
RESISTANCE	6.56427	4.37618	3.28213	2.26571	2.18809	1.8755
1-CR	1.4E-09	9.1E-10	6.8E-10	5.5E-10	4.6E-10	3.9E-10
all-CR	8.7E-08	5.83E-08	4.37E-08	3.5E-08	2.9E-08	2.5E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

FIG. 10

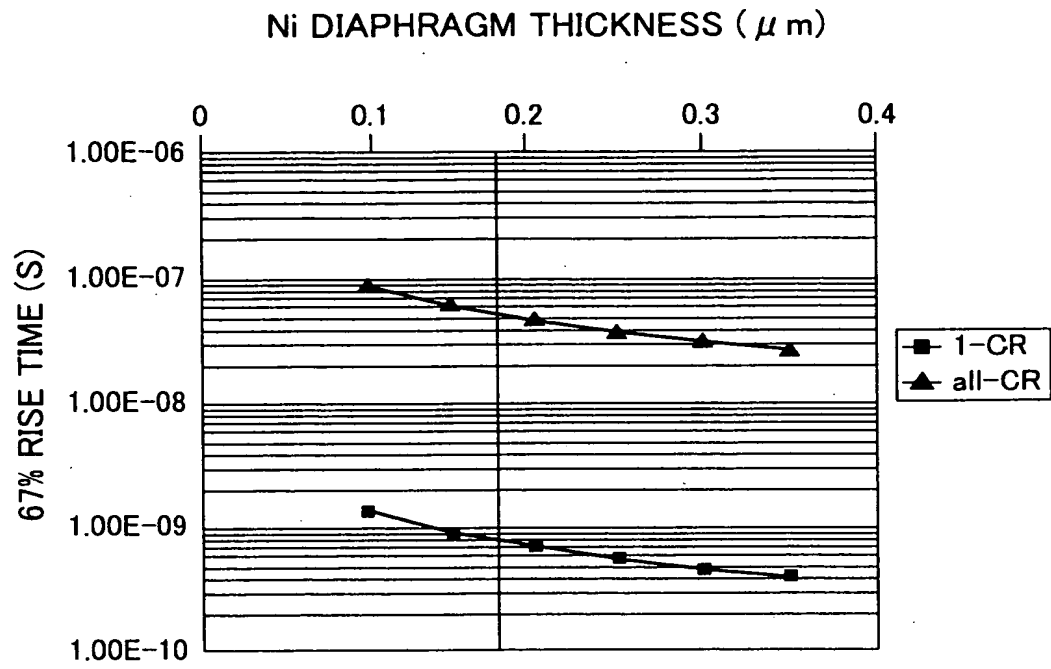


FIG. 11(A)

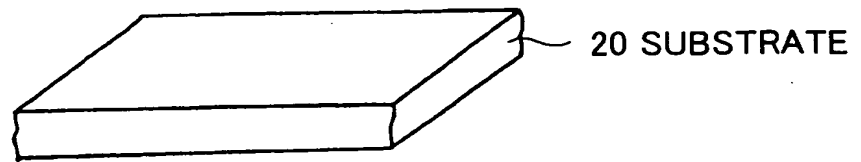


FIG. 11(B)

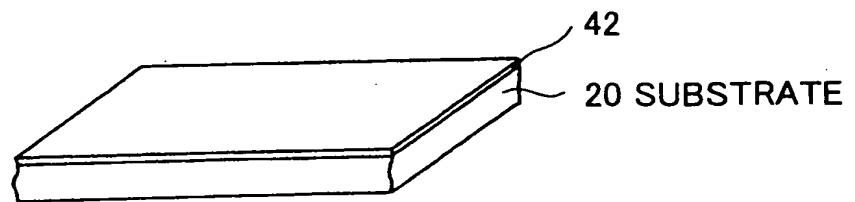


FIG. 11(C)

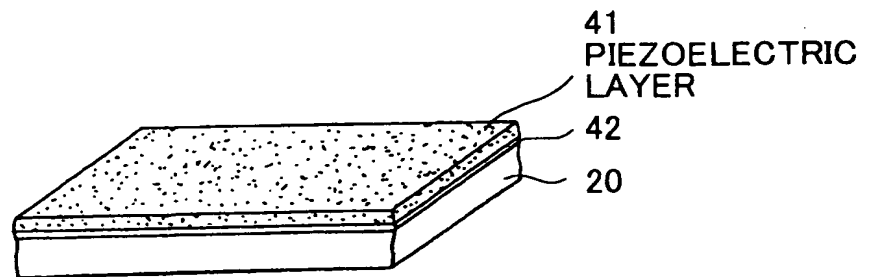


FIG. 11(D)

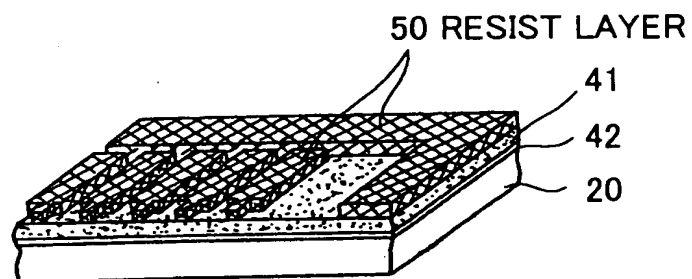


FIG. 11(E)

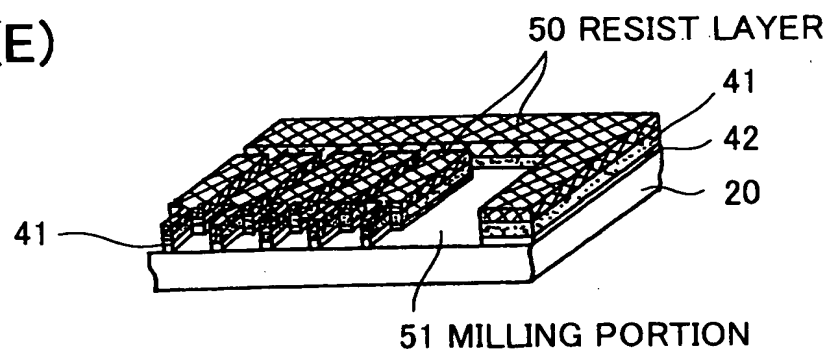


FIG. 12(F)

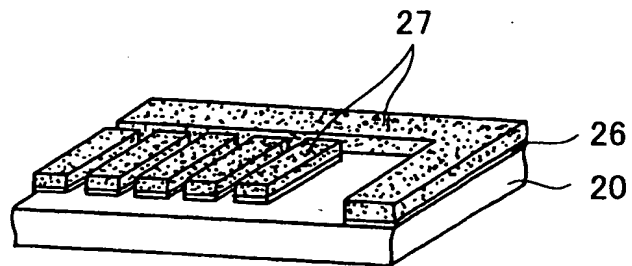
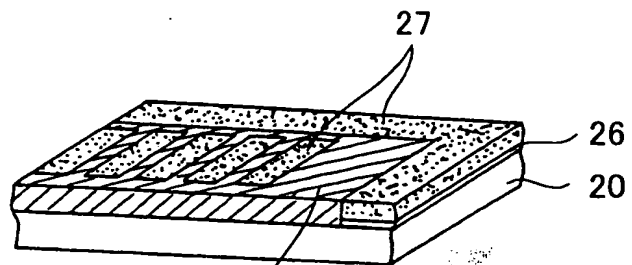
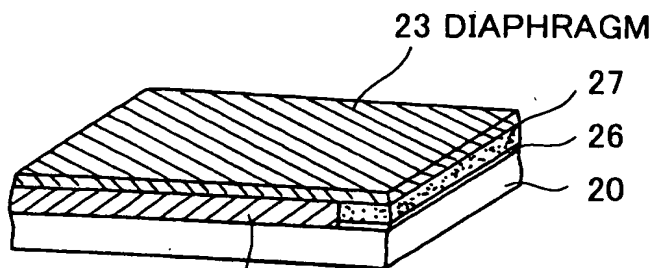


FIG. 12(G)



52 FLATTENING LAYER

FIG. 12(H)



52

FIG. 12(I)

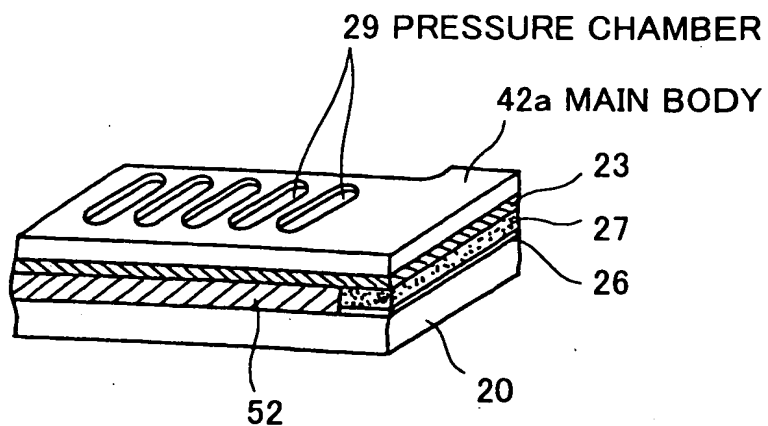
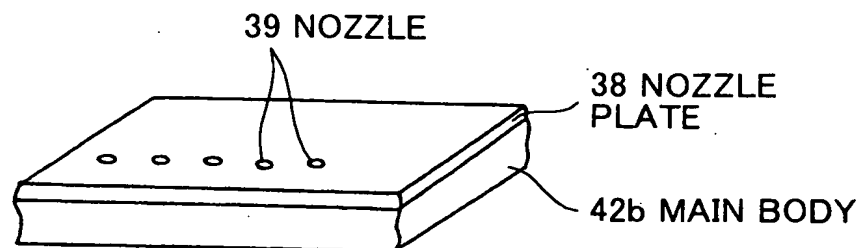
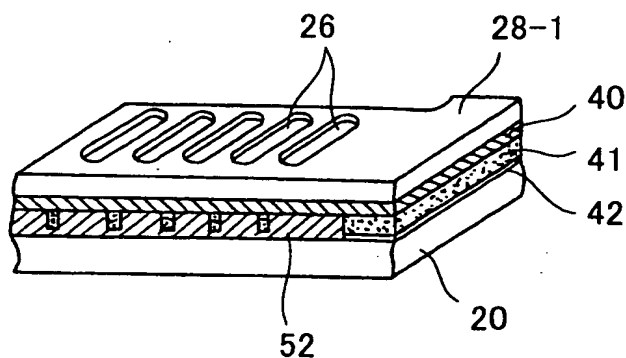


FIG. 13(J)



JOIN



REVERSE

FIG. 13(K)

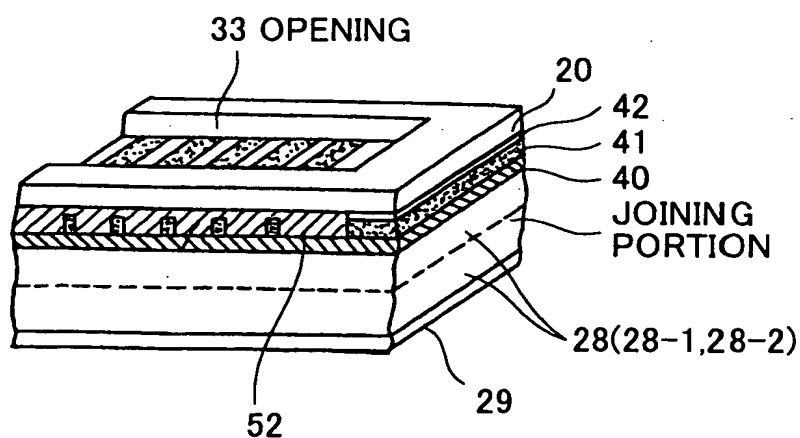


FIG. 14

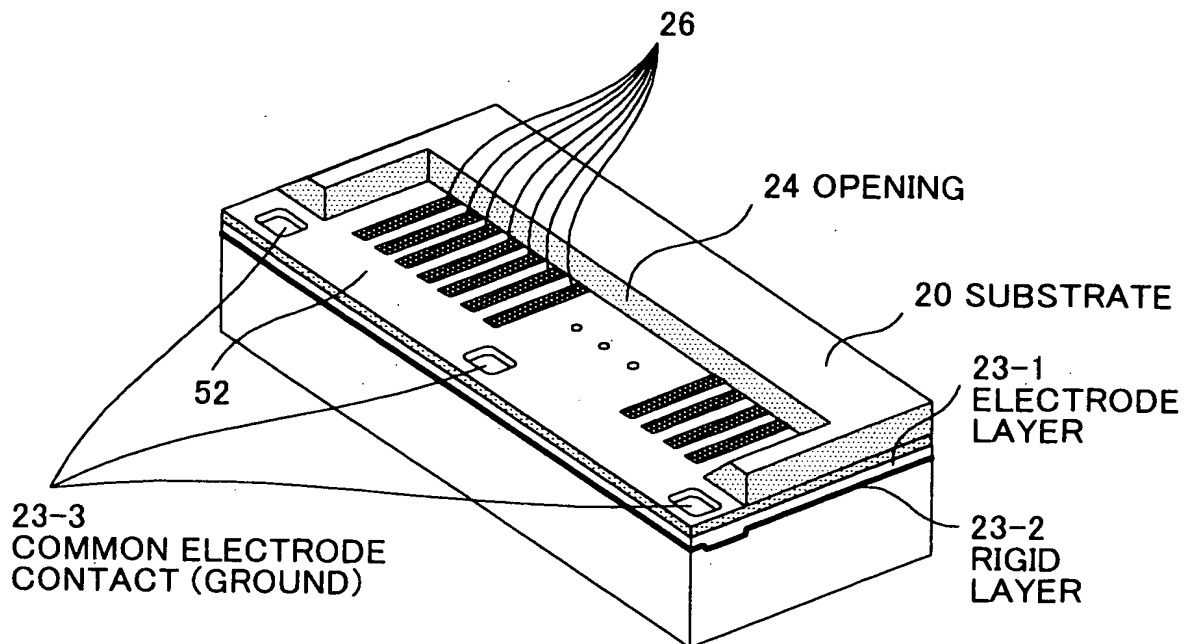


FIG. 15

NOZZLE PITCH (m)	1.70E-04	← THREE POINTS ARE EARTHED AT 64 PIN	
THE NUMBER OF NOZZLES	21		
COMMON ELECTRODE LENGTH (m)	1.96E-03	← DISTANCE FROM BLOCK CONTACT	
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF)	208.152
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	4440.58

CrTHICKNESS	0.1	0.12	0.14	0.16	0.18	0.2
RESISTANCE	14.6596	12.2164	10.4712	9.16228	8.14425	7.32982
1-CR	3.05E-09	2.54E-09	2.18E-09	1.91E-09	1.70E-09	1.53E-09
all-CR	6.51E-08	5.42E-08	4.65E-08	4.07E-08	3.62E-08	3.25E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

FIG. 16

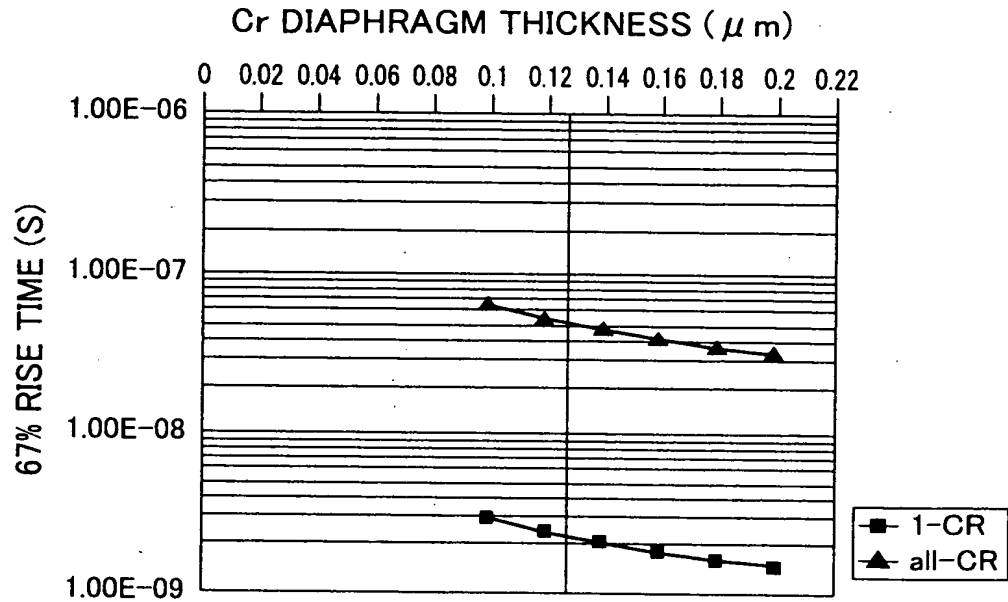


FIG. 17

RESISTANCE Ni : $\rho (\Omega \cdot \text{m})$	7.24E-08
--	----------

NOZZLE PITCH (m)	1.70E-04	←THREE POINTS ARE EARTHED AT 64 PIN	
THE NUMBER OF NOZZLES	21		
COMMON ELECTRODE LENGTH (m)	1.94E-03	←DISTANCE FROM BLOCK CONTACT	
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF)	208.152
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	4371.19

Ni THICKNESS	0.02	0.04	0.06	0.08	0.1	0.12
RESISTANCE	41.2289	20.6144	13.743	10.3072	8.24577	6.87148
1-CR	8.58E-09	4.29E-09	2.86E-09	2.15E-09	1.72E-09	1.43E-09
all-CR	1.80E-07	9.01E-08	6.01E-08	4.51E-08	3.60E-08	3.00E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

FIG. 18

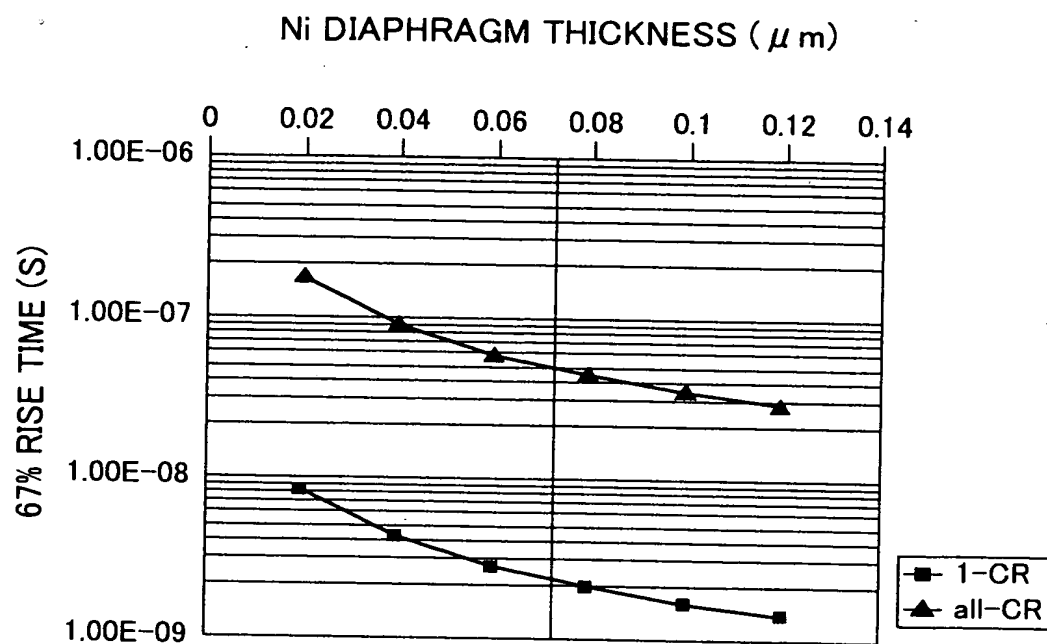


FIG. 19

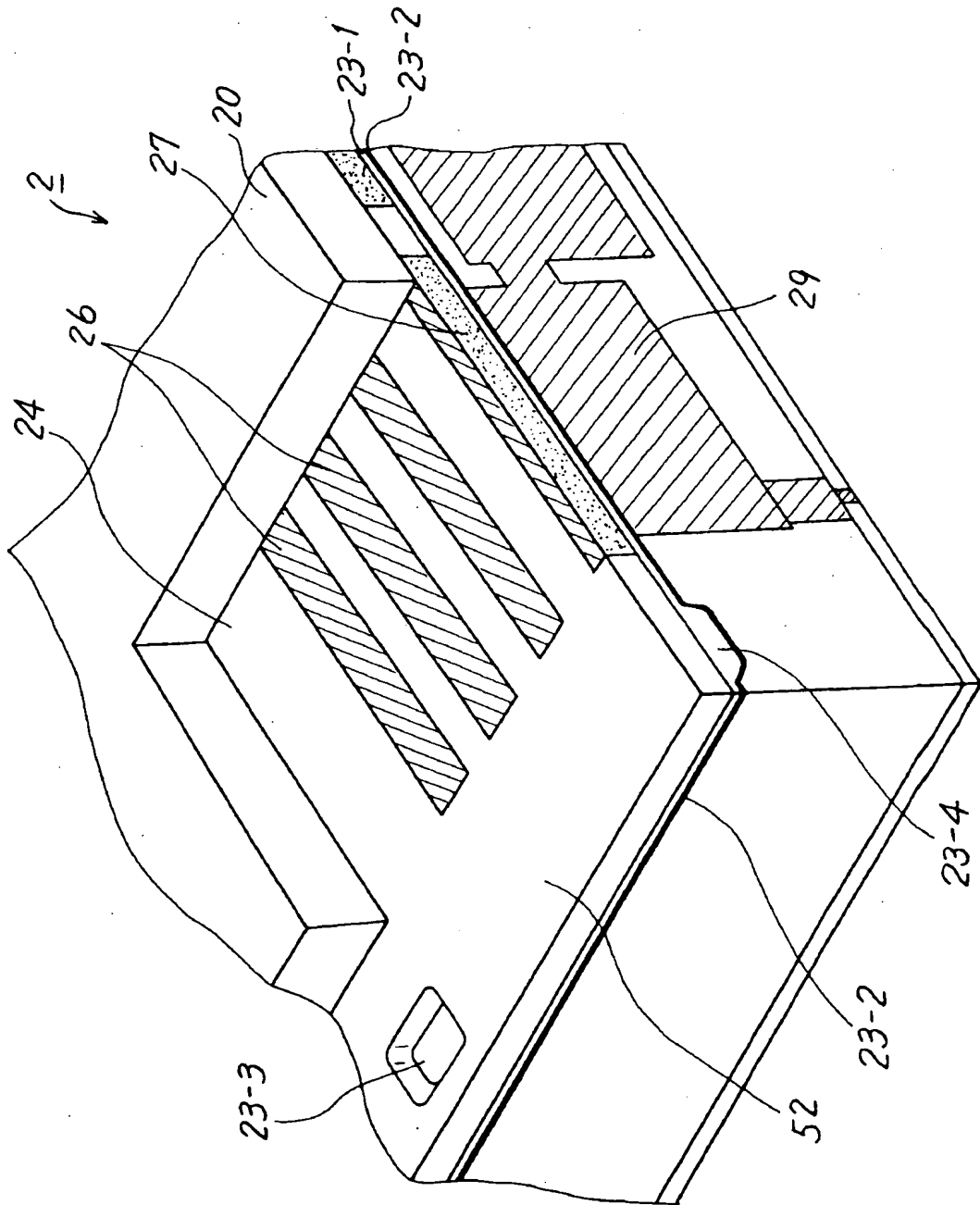
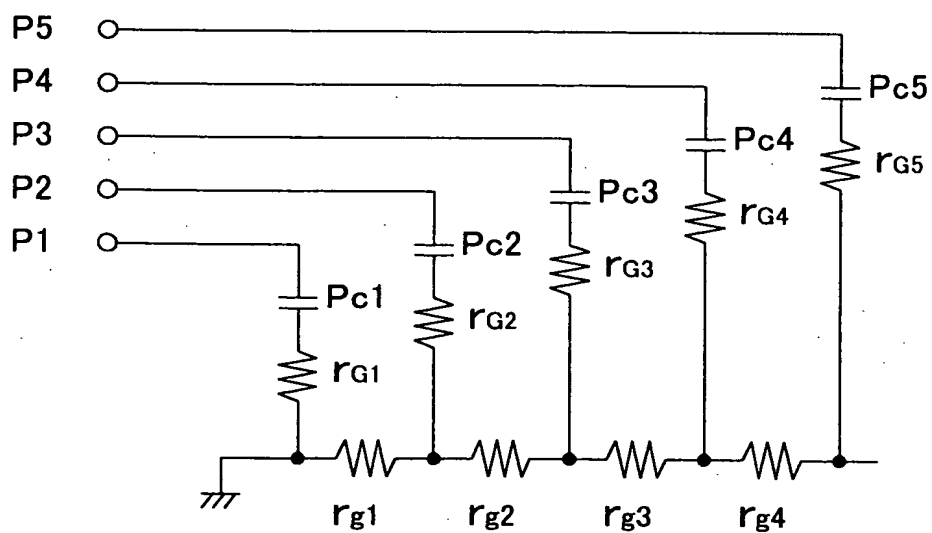
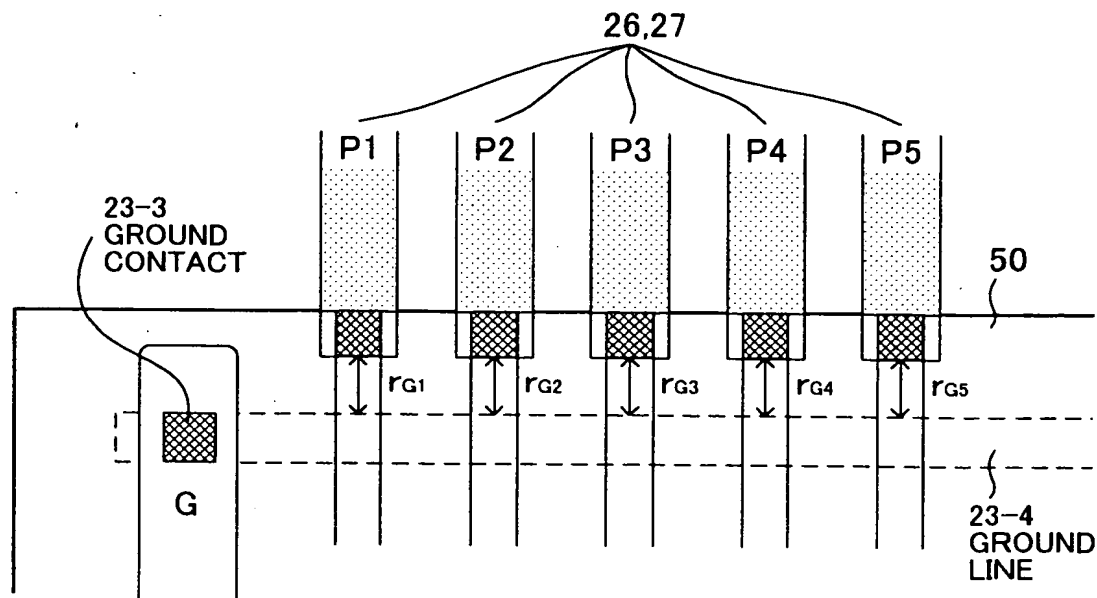


FIG. 20



$$Pc1=Pc2=Pc3=Pc4=Pc5$$

$$r_{G1}=r_{G2}=r_{G3}=r_{G4}=r_{G5}$$

FIG. 21(L)

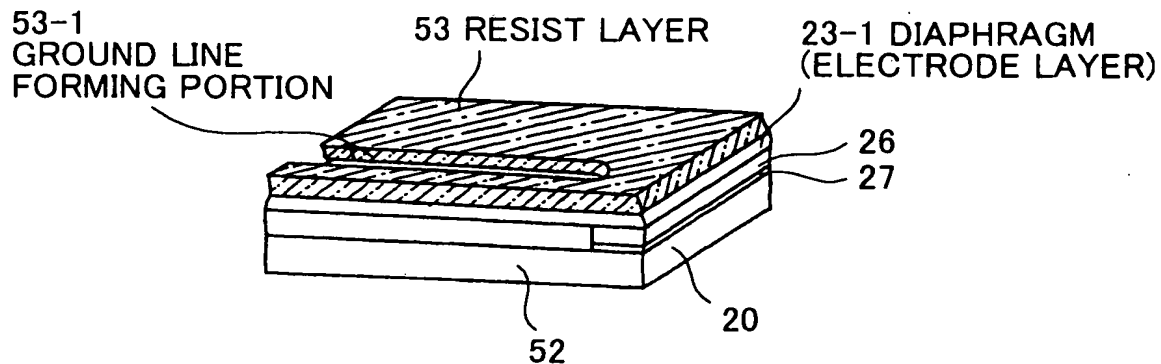


FIG. 21(M)

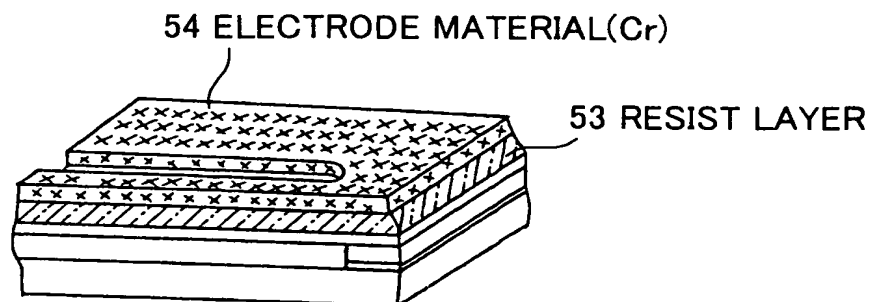


FIG. 21(N)

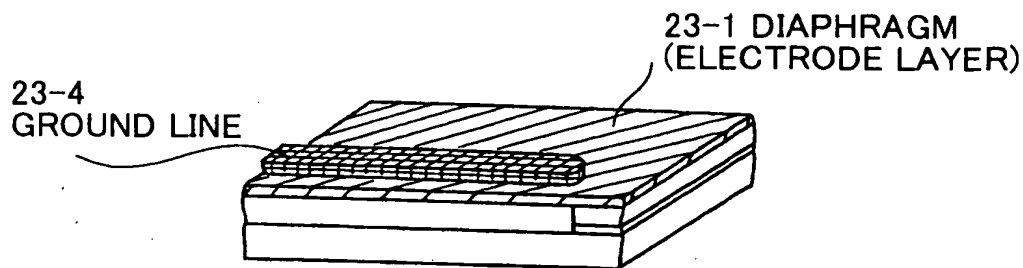


FIG. 21(O)

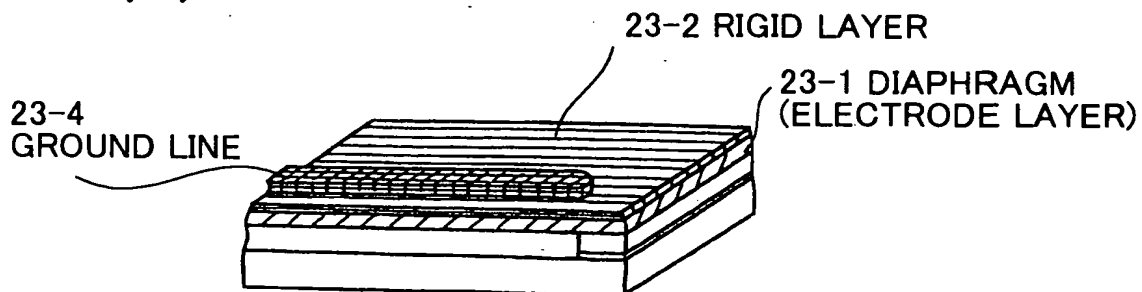


FIG. 22

NOZZLE PITCH (m)	1.70E-04	←DISTANCE FROM GROUND LINE TO PZT CENTER		
THE NUMBER OF NOZZLES	64			
COMMON ELECTRODE LENGTH (m)	7.50E-04			
GROUND LINE WIDTH (m)	6.00E-05			
GROUND LINE THICKNESS (m)	1.60E-06			
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF)	208.152	
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	13321.7	

CrTHICKNESS	0.01	0.05	0.1	0.15	0.2	0.25
1-RESISTANCE	63.2261	18.4025	12.7996	10.932	9.99814	9.43784
1-CR	1.3E-08	3.8E-09	2.7E-09	2.3E-09	2.1E-09	2E-09
128-CR	5.96E-08	5.03E-08	4.91E-08	4.9E-08	4.9E-08	4.8E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE
128-CR : WAVEFORM RISE TIME WHEN 128 PINS DRIVE

FIG. 23

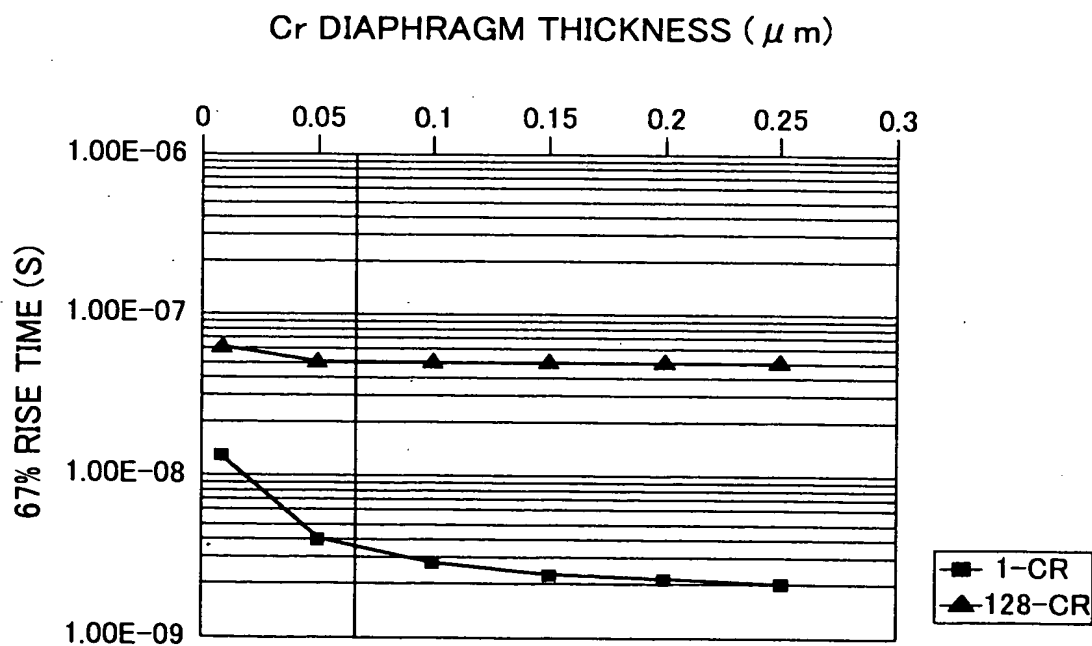


FIG. 24

RESISTANCE Ni : $\rho (\Omega \cdot m)$	7.24E-08
---	----------

NOZZLE PITCH (m)	1.70E-04	← DISTANCE FROM GROUND LINE TO PZT CENTER		
THE NUMBER OF NOZZLES	64			
COMMON ELECTRODE LENGTH (m)	7.50E-04			
GROUND LINE WIDTH (m)	6.00E-05			
GROUND LINE THICKNESS (m)	1.00E-06			
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF)	208.152	
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	13321.7	

NI THICKNESS	0.002	0.01	0.05	0.1	0.15	0.2
1-RESISTANCE	166.27	38.5054	12.9525	9.75838	8.69368	8.16133
1-CR	3.5E-08	8E-09	2.7E-09	2E-09	1.8E-09	1.7E-09
all-CR	7.70E-08	5.04E-08	4.51E-08	4.4E-08	4.4E-08	4.4E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

FIG. 25

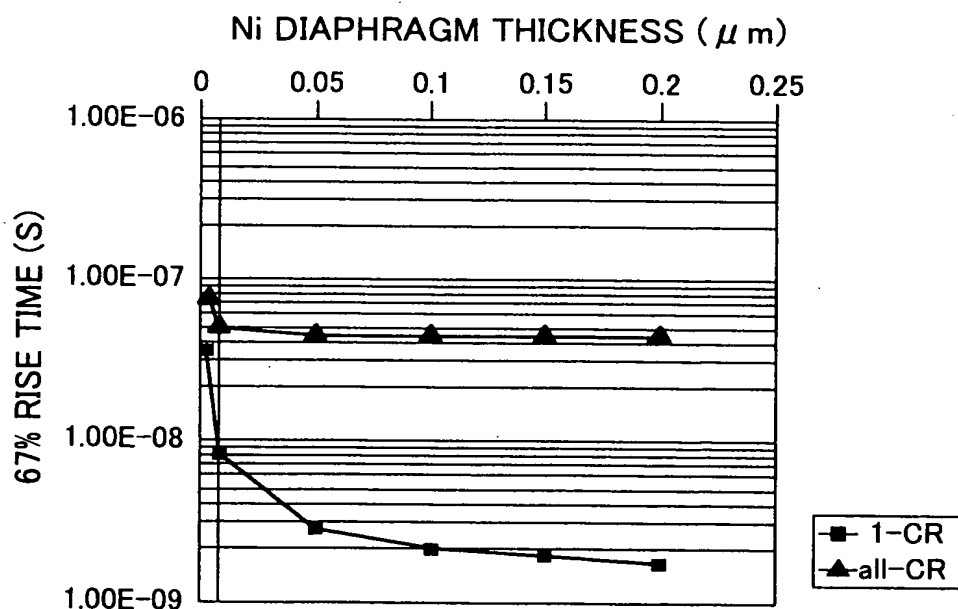


FIG. 26

PRESSURE CHAMBER LENGTH $L_c(m)$	5.00E-04
SIGNAL LINE LENGTH L_{sig}	1.00E-04
PIEZO THICKNESS $t_p(m)$	1.00E-06
PIEZO WIDTH $w_p(m)$	4.50E-05

VACUUM PERMITTIVITY ϵ_0	8.85E-12
PIEZO SPECIFIC PERMITTIVITY ϵ / ϵ_0	420

PIEZO CAPACITANCE $C_p(pF)$	100.359
$C_p = \epsilon * (L_v + L_{sig}) * w_p / t_p$	

RESISTANCE $C_r : \rho (\Omega \cdot m)$	1.27E-07
--	----------

NOZZLE PITCH (m)	8.50E-05	←DISTANCE FROM GROUND LINE TO PZT CENTER		
THE NUMBER OF NOZZLES PER SINGLE EARTH	64			
COMMON ELECTRODE LENGTH (m)	7.50E-04			
GROUND LINE WIDTH (m)	2.00E-05			
GROUND LINE THICKNESS (m)	1.10E-06			
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF)	100.359	
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	6422.98	

FIG. 27

CrTHICKNESS	0.001	0.005	0.01	0.02	0.1	0.2
1-RESISTANCE	1136.29	239.819	127.761	71.7312	26.9077	21.3048
1-CR	1.1E-07	2.4E-08	1.3E-08	7.2E-09	2.7E-09	2.1E-09
all-CR	1.63E-07	7.29E-08	6.17E-08	5.60E-08	5.2E-08	5.1E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE

all-CR : WAVEFORM RISE TIME WHEN 128 PINS DRIVE

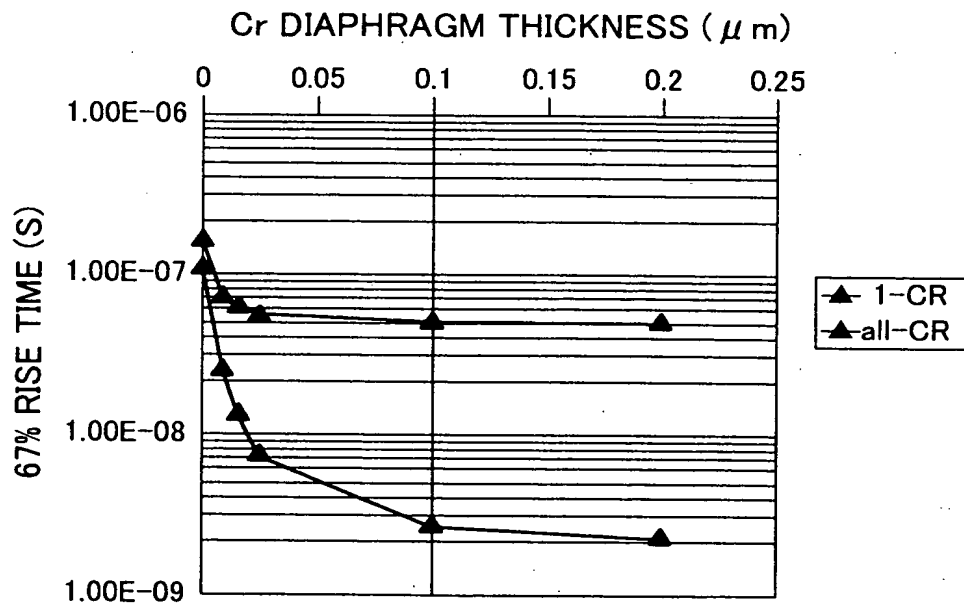


FIG. 28

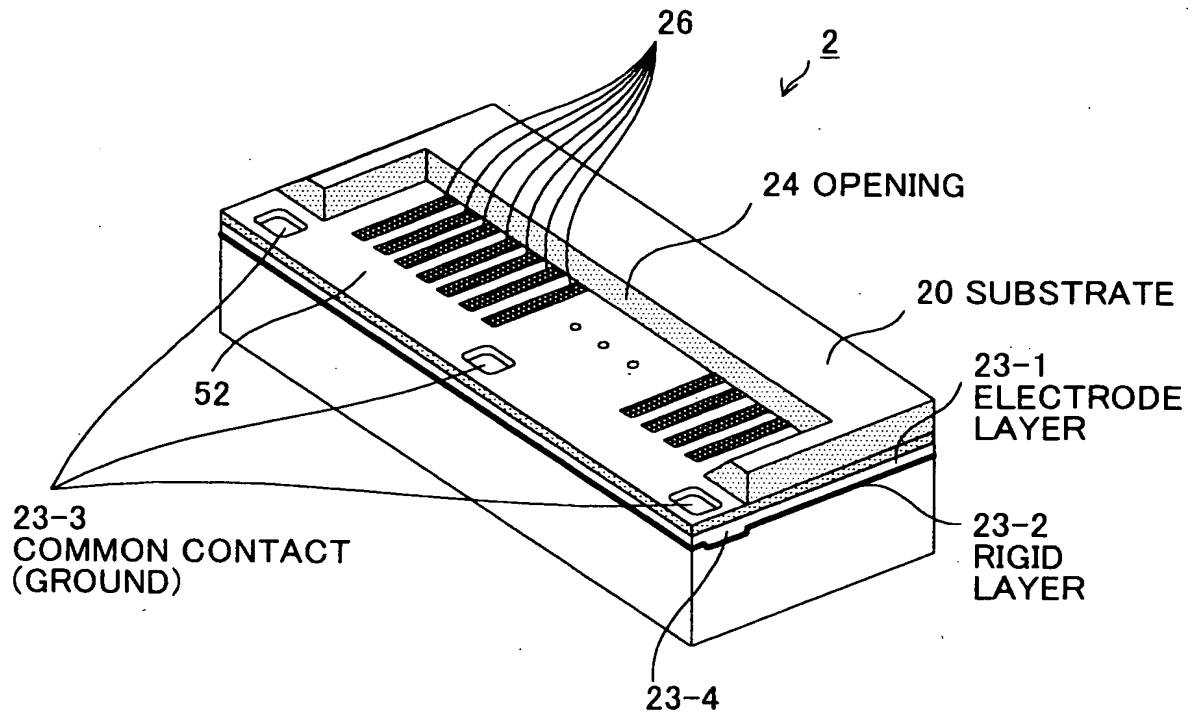


FIG. 29

NOZZLE PITCH (m)	1.70E-04		
THE NUMBER OF NOZZLES PER SINGLE EARTH	43	←THREE POINTS ARE EARTHED AT 128 PINS	
COMMON ELECTRODE LENGTH (m)	7.50E-04	←DISTANCE FROM GROUND LINE TO PZT CENTER	
GROUND LINE WIDTH (m)	2.10E-05		
GROUND LINE THICKNESS (m)	2.00E-06		
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF)	208.152
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	8950.54

CrTHICKNESS	0.001	0.005	0.01	0.02	0.1	0.2
1-RESISTANCE	571.346	123.111	67.0814	39.0667	16.655	13.8535
1-CR	1.2E-07	2.6E-08	1.4E-08	8.1E-09	3.5E-09	2.9E-09
all-CR	1.66E-07	7.28E-08	6.11E-08	5.53E-08	5.1E-08	5.1E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE
all-CR : WAVEFORM RISE TIME WHEN 128 PINS DRIVE

FIG. 30

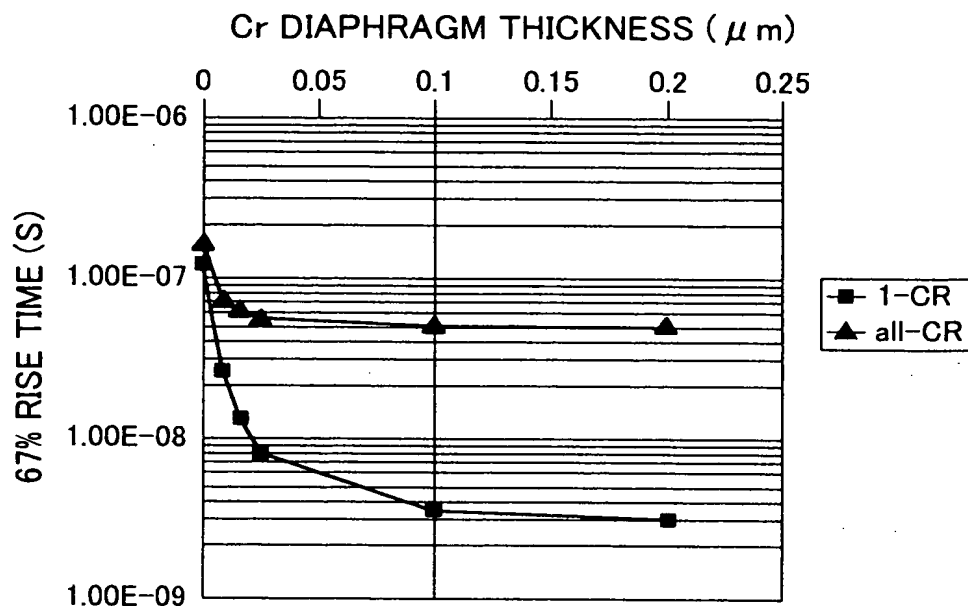


FIG. 31

RESISTANCE Ni : ρ ($\Omega \cdot \text{m}$)	7.24E-08
--	----------

NOZZLE PITCH (m)	1.70E-04	← 128 PINS ARE EARTHED AT THREE POINTS ←DISTANCE FROM GROUND LINE TO PZT CENTER	
THE NUMBER OF NOZZLES	43		
COMMON ELECTRODE LENGTH (m)	7.50E-04		
GROUND LINE WIDTH (m)	1.20E-05		
GROUND LINE THICKNESS (m)	2.00E-06		
APPLIED VOLTAGE (V)	20	SINGLE PIN DRIVE (pF)	208.152
WAVEFORM RISE TIME (ns)	50	ALL PIN DRIVE (pF)	8950.54

Ni THICKNESS	0.001	0.005	0.01	0.015	0.1	0.2
1-RESISTANCE	330.438	74.9083	42.9671	32.32	14.22	12.623
1-CR	6.9E-08	1.6E-08	8.9E-09	6.7E-09	3E-09	2.6E-09
all-CR	1.16E-07	6.26E-08	5.60E-08	5.38E-08	5E-08	5E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE
all-CR : WAVEFORM RISE TIME WHEN ALL PIN DRIVE

FIG. 32

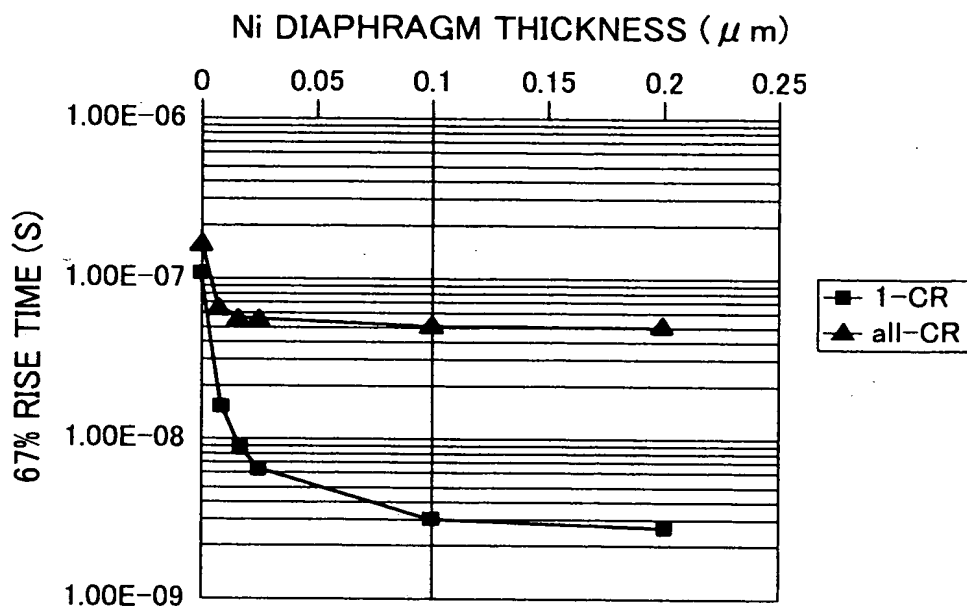


FIG. 33

CrTHICKNESS	0.001	0.005	0.01	0.02	0.1	0.2
1-RESISTANCE	1143.8	247.327	135.268	79.2387	34.4151	28.8122
1-CR	1.1E-07	2.5E-08	1.4E-08	8E-09	3.5E-09	2.9E-09
all-CR	1.63E-07	7.26E-08	6.13E-08	5.57E-08	5.1E-08	5.1E-08

1-CR : WAVEFORM RISE TIME WHEN SINGLE PIN DRIVE

all-CR : WAVEFORM RISE TIME WHEN 150 PINS DRIVE

FIG. 34

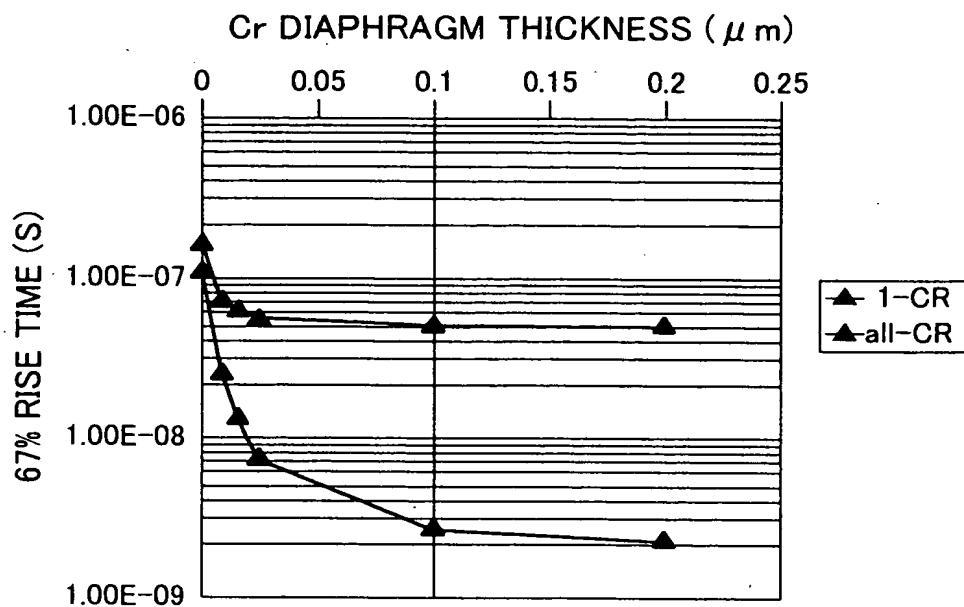


FIG. 35

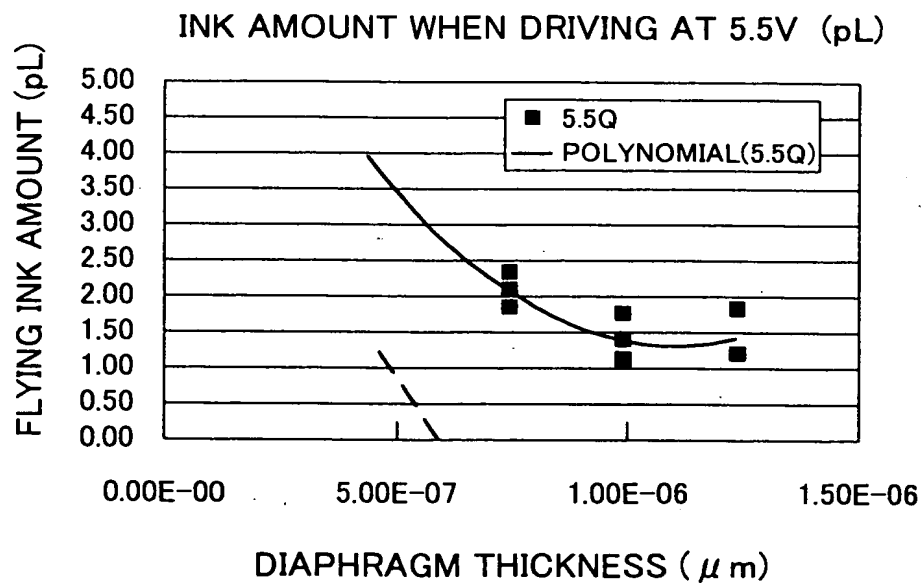


FIG. 36

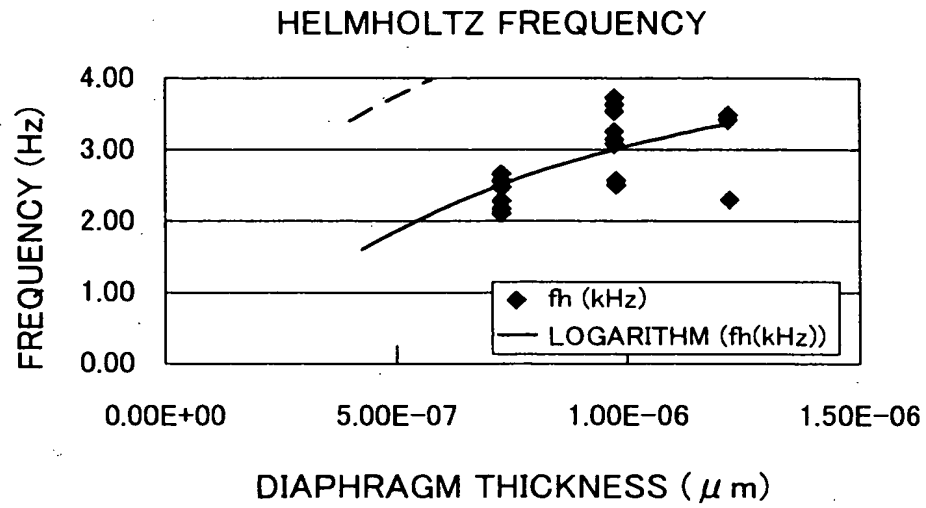


FIG. 37

